Comments on ET Docket No. 03-137, NPRM on RF Exposure

Topic: Spatial Averaging

Summary: *Spatial averaging is an important technique that can be used in assessing an RF environment. It is important to consider:*

- *where spatial averaging is inappropriate and potentially dangerous.*
- *the importance of spatial averaging in reducing the amount of measurement uncertainty in various RF environments.*
- *the practical implementation of spatial averaging.*
- *the variables in spatially-averaged measurements.*

Where NOT to Use Spatial Averaging

Spatial averaging cannot be used without first considering the biological basis of the FCC Regulations and major worldwide standards. The most grievous misuse of spatial averaging occurs when an individual is exposed to a very strong RF field over part of his or her body when in close proximity to an antenna. For example, this can happen when climbing a tower when the climber winds up with his head in the aperture of TV or FM radio antenna. It would be biologically unsound to allow exposure to 1,000 percent of the MPE limits to the climber's head using the logic that his head is equal to about 10 percent of his height. A similar situation can occur with the panel, or sector, antennas used for wireless services, although the field levels from these systems are much lower. This situation can be even more dangerous if the source operates at microwave frequencies where the risk to the eyes is much higher.

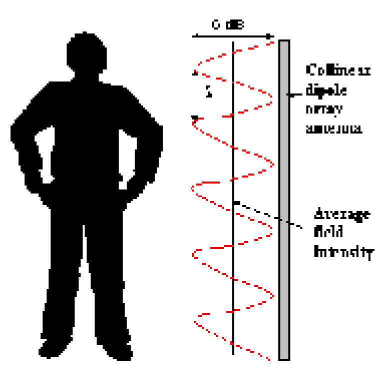
Using Spatial Averaging to Reduce Measurement Uncertainty

Spatial averaging can significantly reduce the amount of measurement uncertainty. The reasons why this is important vary with the type of RF environment. The two most common situations occur near:

1. Wireless systems antennas
2. Radio and television broadcast antennas

Wireless Systems Antennas

Most wireless systems antennas are co-linear dipole arrays. These antennas are made up of a series of radiating elements that are normally spaced one wavelength apart. A common measurement requirement is to determine the strength of the RF field on a rooftop near one or more of these antennas. Even if there is only a single antenna to consider and its output power is held constant, it is possible to obtain field level measurements that vary by up to 6 dB above exactly the same point on a rooftop. This is because there is roughly a 6 dB or 4:1 ratio between each peak of the electric field and each null. Since the radiating elements are spaced one wavelength apart, the vertical distance between peak and



null is only a half wavelength. If an "X" is marked on the roof and two measurements are made directly above that point, a difference of about 6–7 inches in height can yield readings that vary by up to 6 dB at cellular and paging frequencies. At PCS frequencies, the vertical distance between peak and null is about 3 inches. This variance can occur when both measurements are in line with the antenna and is independent of a partial body exposure scenario. In contrast, spatially-averaged measurements will be far more consistent.

Radio and Television Broadcast Antennas

The RF field levels from a TV or FM broadcast antenna are normally quite low at ground level and increase as a function of elevation above the ground with a maximum occurring at an elevation of $\lambda/4$ above the ground. For FM stations this means that the peak fields occur at roughly 2½ feet above the ground. The field intensity then drops off as the elevation is increased. The ratio of field strength from peak to null is typically 8:1 or greater.

Multi-signal environments, typical of the many broadcast antenna farms, are far more complicated because of the various wavelengths and the interactions that take place between fields near ground level. ***Field levels in these environments vary dramatically in all three dimensions and as a function of time.*** Even spatially-averaged measurements will not be totally repeatable. Field levels also vary due to the interaction of the surveyor's body with the field.

Even with all these variables to be considered, spatially-averaged measurements will be far less variable and more meaningful than making measurements based on looking for spatial peaks.

Making Spatially-Averaged Measurements

Some regulations and standards, such as IEEE C95.1, suggest making a series of measurements in a vertical line in increments of 20 centimeters. Although this technique provides some improvement over more random measurements, it has limited accuracy and is very time-consuming. The accuracy of this technique is limited both because of the small number of data points and because the fields may be changing faster than one can make measurements. Consider that 20 centimeters is larger than the distance between a peak and a null from a typical cellular system.

Modern survey instruments are designed to make literally hundreds of measurements during a single spatial average. The technique employed is simple. Pressing a key on the instrument begins data acquisition at a fixed rate that continues until another (often the same) key is pushed. A typical logging rate is 32 data points per second. Thus if a surveyor moves the probe in a vertical line over about ten seconds, the resultant spatial average will be based on more than 300 measurements. If the movement of the probe is at a reasonably constant speed, then the spacing between measurements will be similar.

One can also use this built-in timer function to make spatial averages in two dimensions, such as the box recommended in Canada's Safety Code 6. This is somewhat more difficult to execute, but it is the only practical way to make such measurements.

Variables that Impact Spatially-Averaged Measurements

A very experienced surveyor can usually make fairly repeatable spatially-averaged measurements. However, the more non-uniform the field levels, the greater the variance that can be expected. The fields at complex broadcast sites can vary dramatically in intensity over a distance of a few inches *in any direction*. It often requires at least five spatially-averaged measurements in the same location to have the confidence that a reasonably accurate measurement has been made. And it is not just a matter of averaging the spatially-averaged measurements. Experience helps the surveyor to learn which measurements should be ignored.

Assuming that the surveyor does not move his or her feet, the averages can vary because of a non-uniform rate of speed and/or because the probe is moved over a slightly different area. If field levels are highest at head height, a slight delay in stopping the measurement adds a disproportionate amount of energy from the highest field area to the average. Similarly, if the highest field levels are near the ground, a slight delay in starting to move the probe after pushing "start" can have similar results.

If the surveyor moves his or her body and attempts to make spatial averages over the same point on the ground, one often sees very large differences in readings due to the influence of the surveyor's body on the measurements. In some cases, the body can block the energy from reaching the area being measured. In other cases, the probe may detect energy that is a combination of the actual field and of some additional energy that reflects off the surveyor's body.

One highly regarded expert in the field who has made thousands of spatially-averaged measurements believes that it is very difficult to repeat the same measurement within 5 percent even when the greatest care is taken. This assumes that:

- The surveyor does not move and attempts to measure the exact same spot.

- That nothing changes in the fields that are being measured.

Realistically, if a series of spatially-averaged measurements are within 10 percent of the mean, the surveyor is being very careful.

If a series of spatially-averaged measurements made with the surveyor in one position indicates that the field levels are close to the MPE limits, then it is necessary to make additional measurements to average out the affects of the surveyor's body on the measurements. The best way to do this is to perform 4-5 spatially-averaged measurements while standing in one position and then do the same thing in a minimum of four positions. It is critical to make sure that all measurements are always made with the probe positioned over the same point on the ground. Although this concept may seem obvious, at least one organization has been teaching people to stand in one position and to simply rotate their body. Of course, this results in a series of measurements that are made over different points in a circle that is about 6 to 8 feet in diameter (depending on the length of the surveyor's arm and the length of the probe).

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